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"Rethinking Built Environment: Towards a Sustainable Future"

Organiser:
Research, Industrial Linkages, Community & Alumni Network (PJIM&A)

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Department of Built Environment Studies & Technology (JABT), Faculty of Architecture, Planning & Surveying (FSPU)

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Green Building Occupants' Social Dimensions in the Post Occupancy Stage – Empirical Findings

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Abstract
In the past few decades, scholars have extensively conducted research and held discussions on the sustainable development to elevate the awareness of mitigating environmental problems. Sustainability initiatives have been developed in addressing not only for the environment, but also to the economic and social concerns. In construction, green building substantiates the sustainable development concept when it's designed to balance the environment, economic, and social needs of its occupants. Hence, it is crucial to sustain the green building impacts, not only at the pre-construction stage, but later the post occupancy stage which has the longest period. Nevertheless, amongst of all three sustainability factors, little attention is focused on the social dimensions which include the occupant's comfort and health perception of green buildings. It's even more concerning when many recent studies show discrepancies of occupants' satisfaction in providing better comfort and health in residing green buildings. Therefore, this paper provides the empirical findings on the concept of social needs in providing comfort and health to the occupants and to explore the social factors in green building performance evaluation in post occupancy stage. Eventually, by identifying the social needs of occupants with regards to comfort and health will aid the designers to understand sustainable parameters perceived as important as ones that utilize and reside the building.

Keywords: *Green building, social dimensions, comfort, post occupancy stage*

1.0 Introduction

Building construction and operations is one of the industries that is responsible for sustainable issues; global warming. Defective building design and operation management will cause the building to operate with an increase of energy demand and contribute a higher energy-related carbon dioxide emission. Globally, building operations are responsible for 40% of global final energy consumption and nearly 33% of greenhouse gas emissions (Tricoire, 2021). In Asia, building operations account for around 50% of global emissions and the percentage would ascend exponentially as more buildings will be constructed to cater its rapid growth on the economies and populations (Tveen, 2021).

Thus, by ensuring new buildings in the future are designed and constructed in a more sustainable and energy-efficient manner, it will be important to address the climate change issues and green building concept is one of the initiatives developed. Generally, the development of green building is not only capable of addressing the climate change issue, but also to create sustainable and thriving communities, as well as driving economic growth (WGBC, 2021). A study by Dodge (2018) compiled what green building is defined, and what criteria must be fulfilled for a building to be considered as green given by 2078 number of respondents. Generally, green building must have efficient use of resources (energy, water, and other resources), reduce pollution and waste by enabling reuse and recycling, promote good indoor environmental air quality, and to consider the environmental needs in the project lifecycle starting from the design, construction until its operation stage.

Green building's benefits can be categorized into three different aspects, which is for the environment, economic, and social. First, the green building is designed as such its operation would consume less water, energy, or natural resources and even to generate its own energy resources (renewable energy), for the purpose of reducing or eliminating the negative impacts on the environment (WGBC, 2021). Green building assessment method is an instrument used in evaluating the sustainable performance of a green building during its design, construction and operation's phase (Li, Chen, Wang, Xu, & Chen, 2017). The overall sustainability level of green building is determined on the performance during the occupancy stage and the operation management level (Li, Xu, & Huang, 2020). Li, Froese, & Brager (2018) added that the actual performance determines whether a building is green or not, and not simply by its design intent. Post occupancy evaluation (POE) is an essential tool in the life-cycle of green buildings to verify the building performance as intended by gathering feedback from the occupants. Preiser, Rabinowitz, & White (1988) defines POE as the "process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time".

Preiser (1995) categorized three phases of POE namely, indicative, investigative and diagnostic. Indicative involves a quick walk-through evaluation involving structured interviews with the building key personnel, investigative involves a more detail process utilizing interviews, survey questionnaires, physical measurements, and lastly diagnostic POE are more focused, longitudinal and cross-sectional evaluation studies emphasizing on safety, orientation and wayfinding, artificial versus spectrum lighting, privacy, overcrowding, and etc. Generally, POE aims to evaluate, assess, or investigate the building performance holistically, by accounting the occupant response, energy consumption, indoor environmental quality (IEQ) and design features of the building (Li et al., 2018).

2.0 Problem Statement

The performance of green buildings in fulfilling the needs of comfort of the occupants is still questionable. It is highlighted in the finding from a study by researchers (Bajraktari, Mahn, & Mueller-Trapet, 2019; Moore & Iyer-Raniga, 2019; Zhao, He, Johnson, & Mou, 2015) where discrepancies between the designed and the actual performance of green buildings were found proving that the green buildings did not ultimately fulfill its design performance goals as determined by the design rating. While most of the existing green building rating systems tend to give credit more in the initial stages of building design, often overlooking the ongoing and long-term implications of the design choices on the building occupants' satisfaction (Mansour & Radford, 2015, 2016).

Altomonte, Schiavon, Kent, & Brager (2019) further added that green building certifications acquired during pre-occupancy stage did not necessarily influence occupants' satisfaction. For instance, building with certified Indoor Environmental Quality (IEQ) credit did not substantively elevate and influence the occupants' workplace satisfaction (Altomonte et al., 2019). Yahuza & Erçin (2020) expressed that green building designers have the problems of balancing the need for environmental, economy and social needs of occupants when green designs may not be able to satisfy the occupants utterly. For instance, an open space layout with the use of lower partitions and full glass windows may create an energy efficient design by allowing as much natural daylighting to penetrate the space. However, this design approach may also compromise the social territories in the absence of privacy space (Mansour & Radford, 2016) and ineffectiveness of blocking the excess natural and artificial lighting (Aigbavboa & Thwala, 2019). Hence, it's essential to reevaluate which green building mandates are perceived important in providing satisfaction in comfort by the occupants.

In addition, previous researches were done to certify whether green buildings are capable of meeting occupant's satisfaction and improve work performance, and if the occupants could feel any differences in occupying conventional buildings and green-rated buildings. Findings showed no significant satisfaction differences were found between these two buildings and this highlighted the need of understanding the performance-satisfaction gap (Altomonte & Schiavon, 2013; Elnaklah, Fosas, & Natarajan, 2020; Mansour & Radford, 2016; Wang & Zheng, 2020).

3.0 Methodology

The review was carried out by systematically searching online literature databases, using keywords, within ten years (10) of time frame. Searches were conducted using online databases Web of Science (WOS) and Scopus using keywords "green building", "post occupancy", and "comfort". To complete the first objective of this study, twenty-seven (27) articles were found and further reviewed as pilot articles. Meanwhile, associated websites were referred mainly to collate the information pertaining to green building evaluation tools.

4.0 Finding and Discussions

The findings from the review were discussed in two (2) topics based on the objective of this study, which are the determination of occupants' needs in providing comfort in green building and overview of existing Malaysian sustainability rating tools as the method of evaluating the comfort needs in green building during the occupancy stage.

4.1 Determining Occupants' Needs in Providing Comfort

Green buildings are designed not only to combat the adverse impact on the environmental and economic factors, but also to fulfill the social benefits by improving the quality of life, health, and well-being of the occupants. The occupant's quality of life can be influenced by the building environment in both favorable, and vice versa. Poor indoor air quality, thermal conditioning, lighting, and specific aspects of interior space design have negative effects such as illness, absenteeism, fatigue, discomfort, stress, and distractions (e.g., materials selections, furnishings, and personnel densities). Yudelson (2007) defines comfort as a condition of mind expressing an occupant's satisfaction with a thermal environment which includes air temperature, radiant surface temperature, air velocity, and relative humidity. Table 1.0 summarized the green building occupant's need in providing comfort performance based on previous POE surveys conducted.

Table 1. Green building occupant's need in providing comfort performance

Physical Factor	Emotional/Cognitive Factor	Environmental Factor
Spatial ● Comfort of furnishing ● Adjustability of work area ● Space to collaborate ● Space to interact with colleague ● Access to sit-stand desk ● Furniture adjustability	**Connection to outdoor environment** ● Sense of connection between work and outdoor ● External view from work area ● Access of daylight from work area	**Indoor Air Quality (IAQ)** ● Environmental tobacco smoke control ● Outdoor air delivery monitoring ● Low emitting material (adhesive, sealant, paints, coatings) ● Indoor chemical pollutants source control ● Odour ● Control of air pollution (TVOC, VOC, formaldehyde and acetaldehyde, nitrogen dioxide NO_2, Sulphur dioxide SO_2, size of particulates matter)
Building maintenance ● Workspace cleanliness ● Building cleanliness	**Spatial** ● Visual aesthetic of work area ● Space for breaks ● Availability greenery and gardens	**Thermal Comfort** ● Ventilation rate ● Temperature ● Availability of natural ventilation
	Biophilia	**Wastewater** ● Separation of greywater
		Visual comfort ● Natural lighting ● Control lighting (artificial lighting) ● Color temperature ● Glare

		● Color and textures of interior
		Personal comfort ● Controllability (lighting, temperature, and humidity) ● Visual privacy ● ICT infrastructure access (touchless technologies)
		Acoustic ● Noise distractions and privacy
		Spatial ● Individual space ● Amount of space

Based on the review, occupants' needs in comfort can be categorized into three different factors, which are the physical factors, emotional and cognitive factors, and environmental factors. Physical factors involve physical activity; facility for the occupants to move and maneuver frequently. Meanwhile, emotional and cognitive factors refers to the emotional experience that affects the moods, well-being, mental health, satisfaction, productivity, and well-being of the occupants. Lastly, the environmental factor concerns on the IEQ which includes thermal comfort, lighting, acoustics, IAQ conditions, personal comfort, and spatial satisfaction (Candido, Marzban, Haddad, Mackey, & Loder, 2021; Elnaklah et al., 2020; Elnaklah, Walker, & Natarajan, 2021; Licina & Langer, 2021; Tokazhanov et al., 2021). These factors listed in Table 1.0 shows how essential it is to thoroughly identify what criteria shall be assessed in providing comfort, and how the occupants' experience and feedback in assisting to verify what perceived as comfort needs. This input shall act as indicator for a more comprehensive POE assessment.

4.2 Overview of Existing Malaysian Sustainability Rating Tools as Method of Evaluating Comfort Needs During Occupancy Stage

Green buildings are primarily evaluated using green rating tools which evaluate and certify the green construction and its performance. The first green rating tool system established by the United Kingdom, known as the "Building Research Establishment Environmental Assessment Method" (BREEAM) back in the year 1990. Eight years later, The United States further developed their own first system called "Leadership in Energy and Environmental Design" (LEED) (Kwong, 2020). Years later, many other countries globally come behind to develop own sustainable tool system, for example, Green Building Council Australia (GREENSTAR), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), German Sustainable Building Council (DGNB), The Green Mark Certification Scheme, and many other (Khan, Wang, & Lee, 2021).

In Malaysia, green rating tools are categorized based on two authority developers and operations, which are government-driven and by the professional associations, designed specifically for the tropical climate (hot and humid) embracing the need of the current national's social, infrastructure, and economic development. Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST), Melaka Green Seal and Penarafan Hijau JKR (PH JKR) are government driven while Green Building Index (GBI) and Green Real Estate (GreenRE) are driven by the professional associations (Hung & Fuad, 2018). GBI was established in 2008 and it's currently one of the most widely used rating systems for building projects. The assessment allows the project stakeholders to obtain a Green Certification in the early stage of the project development, which enables the project team to optimize most strategic planning for the project, reduce costs and maximize the return of investment. Meanwhile, GreenRE was set up by the Housing Developers Association (HDA) Malaysia (REHDA) back in 2013 (Hung & Fuad, 2018; Kwong, 2020). These rating tools generally evaluate on energy efficiency (EE), indoor environmental quality (IEQ), site planning and management, materials and resources, waste and water efficiency, and innovation (Mohd Annuar et al., 2014)

During occupancy assessment in this sustainable rating tools' system, POE is one of the methods used to certify the ability of green buildings in providing social needs in real use conditions (Vásquez-Hernández, Fernando, & Álvarez, 2017). Table 2. summarized the criteria assessed by GBI, MyCREST, PH JKR and Melaka Green Seal, which mainly focus on the comfort and health criteria. The assessment is categorized into two sections based on the stages in a project, which are the assessments during pre-construction, and post occupancy stage.

Table 2. Comfort assessment criteria by Malaysian existing rating tools

Rating tools	Assessment criteria (Pre)	Points given	Assessment criteria (Pre)	Points given
GBI				
NRNC – Version 1 (2009)	Air Quality ● Minimum IAQ Performance ● Environmental tobacco smoke (ETS) Control ● Carbon Dioxide Monitoring and Control ● Indoor Air Pollutants ● Mould prevention Thermal Comfort ● Thermal comfort: Design & Controllability of Systems ● Air Change Effectiveness Lighting, Visual & Acoustic Comfort ● Daylighting ● Daylight Glare Control ● Electric Lighting Levels ● High frequency Ballast ● External views Internal Noise levels	1 1 1 2 1 2 1 2 1 1 1 2 1	Verification ● IAQ during occupancy ● POE survey	2 2
NREB – Version 1.1 - 2011	Air Quality ● Minimum IAQ Performance ● Environmental tobacco smoke (ETS) Control ● Carbon Dioxide Monitoring and Control ● Indoor Air Pollutants ● Mould prevention Thermal Comfort ● Thermal comfort: Design & Controllability of Systems ● Air Change Effectiveness Lighting, Visual & Acoustic Comfort ● Daylighting ● Daylight Glare Control ● Electric Lighting Levels ● High frequency Ballast ● External views Internal Noise levels	1 1 1 2 1 2 1 2 1 1 1 2 1	Verification ● IAQ during occupancy ● POE survey	2 2
RNC - (Version 3.1) - 2014	Air Quality ● Minimum IAQ Performance ● Volatile Organic Compounds Minimisation ● Formaldehyde Minimisation Lighting, Visual and Acoustic Comfort ● Daylighting ● External views Sound insulation	3 2 1 3 1 1	POE survey ● Air quality ● Thermal comfort ● Daylight comfort ● Visual comfort ● Acoustic comfort	1

MyCREST	Air Quality Performance ● AC building – fresh air rate for air ventilation system to comply ASHRAE 62 1:2007 ● Non-AC building- minimum fresh air ventilation in conjunction with mechanical ventilation system to follow local Indoor Smoking Restrictions ● Floor plan to display signage on smoking-restricted areas Control & Strategies to reduce mould occurrence Indoor Air Quality Pollutants ● Low VOC materials – paints and coatings ● Low VOC materials- adhesive and sealants Carbon dioxide level control ● CO2 monitoring system	Required Required Required 1 1 1 1	Occupant Comfort ● Questionnaires ● Survey analysis Indoor Air Quality Performance ● Maintenance Low-VOC Materials (Paint & Coatings) ● Maintenance of Low-VOC Martials- Adhesives & Sealants Indoor Air Quality test (Quality Report) Green Cleaning Policy Purchase Eco Cleaning Products/Equipment ● Purchase 30% of total annual purchase (product) ● Purchase 30% of total annual purchase (equipment)	1 1 1 1 1 1 1
	Social and cultural responsibility Design for social responsibility (disable facilities) Access to view from work areas Compatibility of urban and façade design to cultural values Maintenance of heritage value of existing facilities	1 1 2 1 1	Indoor Integrated Pest Management Thermal comfort monitoring Control of mould occurrence	1 1 1
PH JKR	Space Planning ● Arrangement of office space along façade ● Partition wall with light penetration ● maximizing external view ● no deep planning ● effective ceiling height ● bright color for wall and ceiling Daylighting ● design window with daylight factor ● light shelves Thermal comfort **Visual comfort** ● space arrangement without barrier ● glare control ● lighting in room **Acoustic comfort**	1 1 1 1 1 1 1 2 3 1 1 1 1	Survey on occupants' comfort	3

	Indoor Air Quality ● use of low VOC materials ● Prohibition of smoking ● Indoor air quality performance ● Control of carbon dioxide level ● Mould control	 1 1 1 1 2		
Melaka Green Seal	**IEQ** ● Comply with ASHRAE 61.1-2007/Local building code ● Sound insulation ● Quality daylighting ● Low emission paint/ materials	 1 1 1 1	-	-

Based on findings in Table 2, it is apparent that credits in the assessment are given more in the pre-construction stage, while less points are given in the assessment during the occupancy stage. Most of the existing rating systems tend to evaluate the initial stages and lacking long term concerns on the later stage, the occupancy stage. Meanwhile, it is the involvement of the occupants that will verify the ongoing success of sustainable performance of the building with regards to social needs primarily (Mansour & Radford, 2016). This finding may trigger an argument that the current rating tool shall be reevaluated by giving more attention on the POE assessment, to fulfill the social needs of the occupants.

5.0 Conclusion

To conclude, the findings suggested that the current evaluation rating tools may assist in collating experience and feedback of the occupants in fulfilling their comfort needs. However, the discrepancy evidence on green building proving better comfort shall not come across in any POE survey, as one of the pillars of green building objective, is to provide social benefits for the occupants. Hence, it's important to have continuous research on identifying the green building's social needs and it shall behave as the input to improve the criteria assessed in the post occupancy stage.

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